Applications of ATMS/CrIS to Tropical Cyclone Analysis and Forecasting

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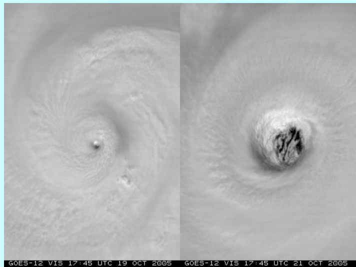
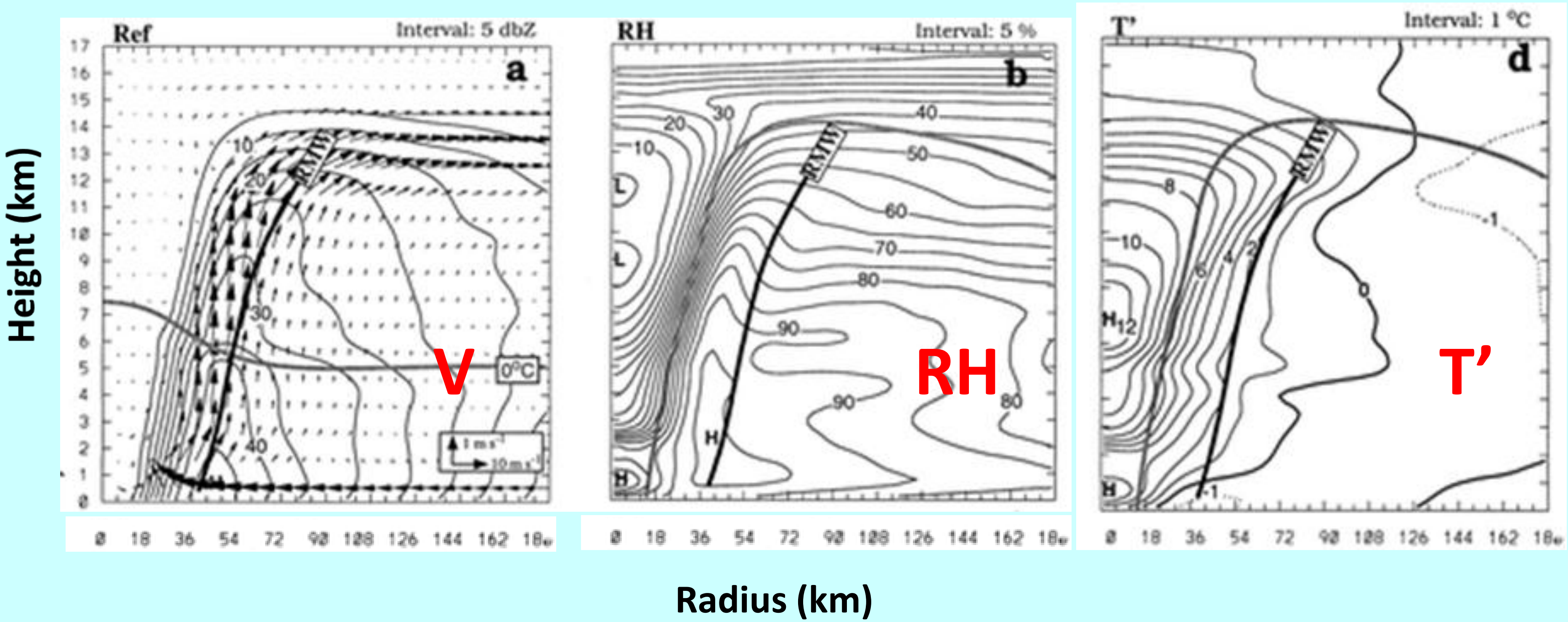


Outline

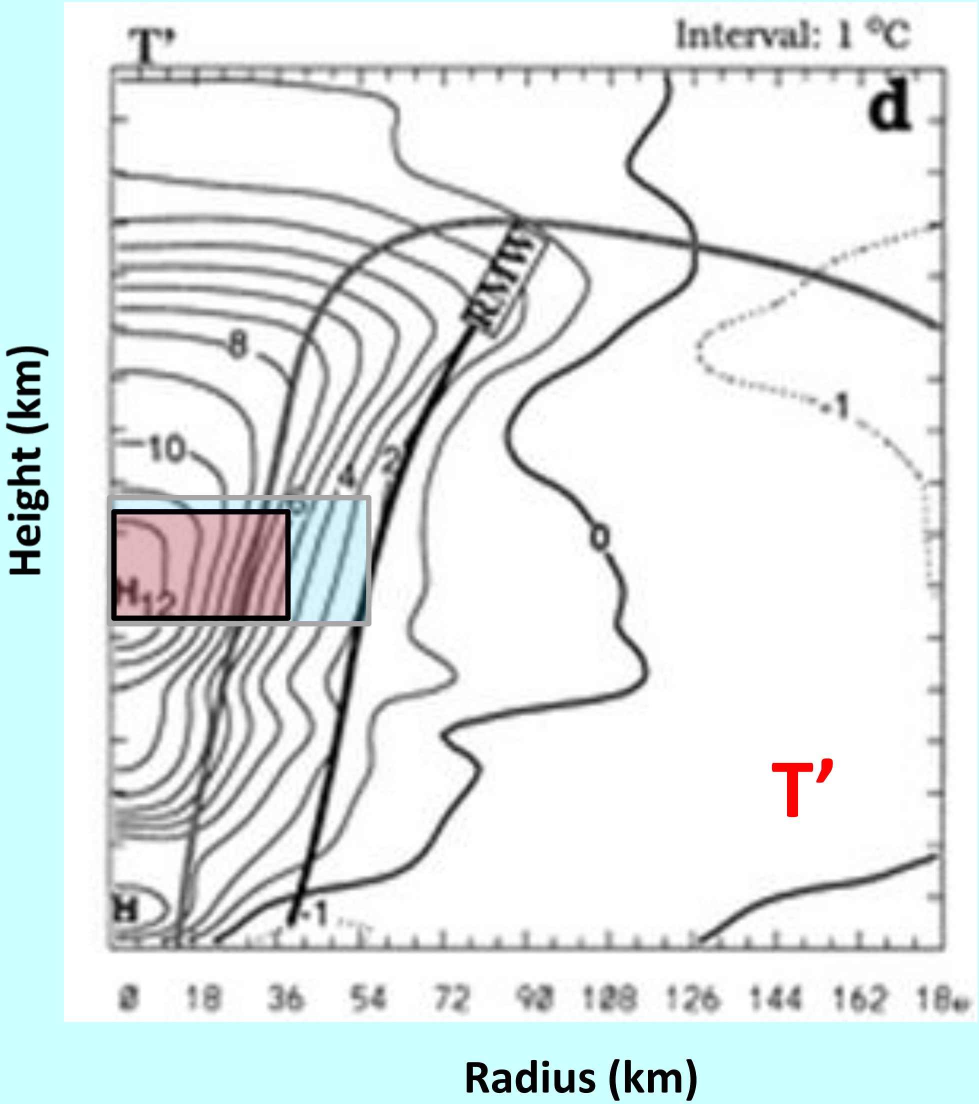
- Tropical Cyclone warm core
- Hydrostatic and nonlinear balance
- Operational AMSU tropical cyclone products
  - Intensity and wind structure estimation
  - Transition to ATMS
- Applications to intensity prediction
  - Maximum Potential Intensity estimation
  - Tropical Vertical Instability
- Center fixing from VIIRS and ATMS

Hurricane Warm Core Structure



From Liu, Y., D.-L. Zhang, and M.K. Yau, 1999: A multiscale numerical study of Hurricane Andrew (1992). Part II: Kinematics and Inner-Core Structures. JAS.

Hurricane Warm Core Structure



Hydrostatic Balance

$dp/dz = -\rho g$

$p = \rho R T_v$

$$\int_{P_{top}}^{P_{sfc}} dp/p = -\int_{Z_{top}}^{0} (g/RT_v)\,dz$$

p = pressure

z = height

ρ = density

g = gravity

T_v = virtual temperature

R = ideal gas constant

Given T,RH retrieval, T_v can be used to estimate surface pressure through downward integration.

Pressure-Wind Relationships

- Hydrostatic integration and ideal gas law give P, ρ
- Approximate form of horizontal momentum equations provides horizontal wind estimates
  - Valid above the boundary layer
- Symmetric flow – gradient wind

$$V^2/r + fV = (1/\rho)\partial p/\partial r$$

- Asymmetric flow – Nonlinear balance equation

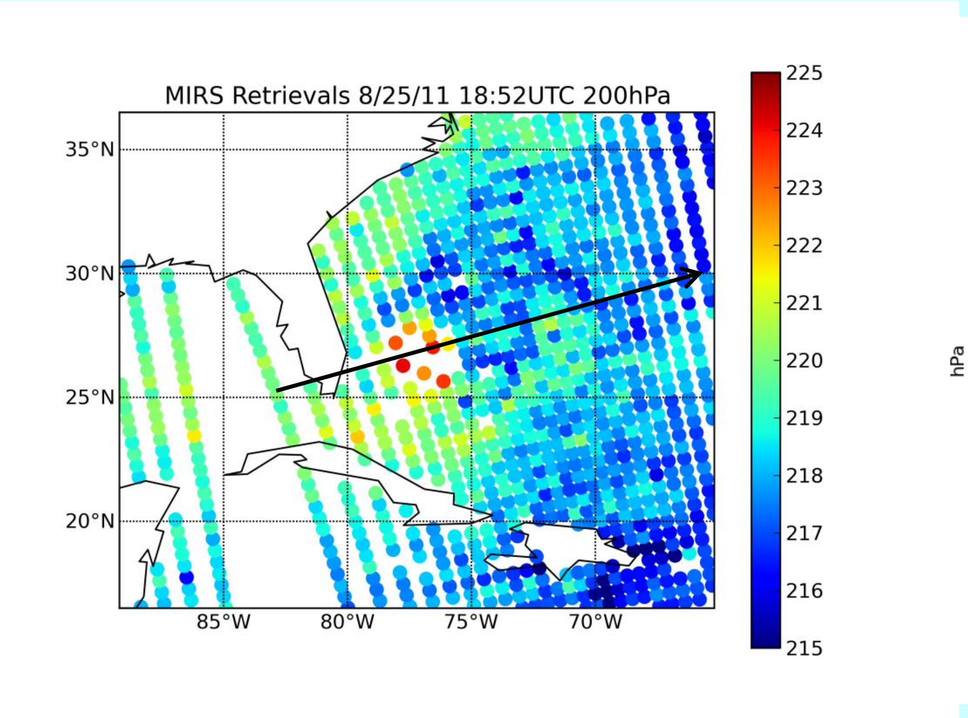
$$u_x u_x + 2v_x u_y + v_y v_y - \zeta(f + \beta y) + \beta u + \nabla^2\phi = 0$$

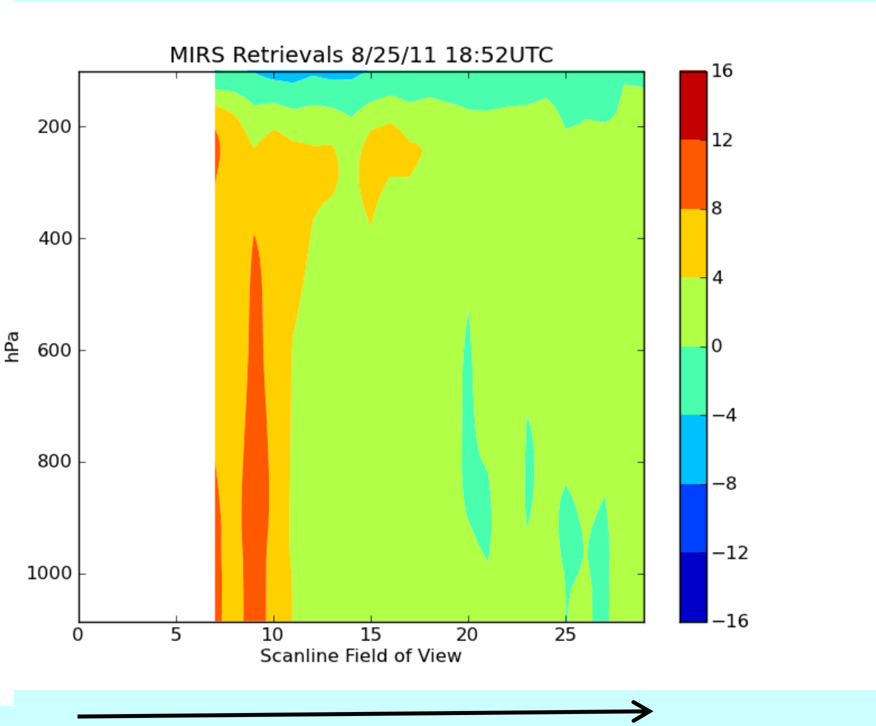
$\nabla^2\phi =$ **Pressure term from Sounding, u,v = horizontal wind components**

Operational AMSU Tropical Cyclone Products

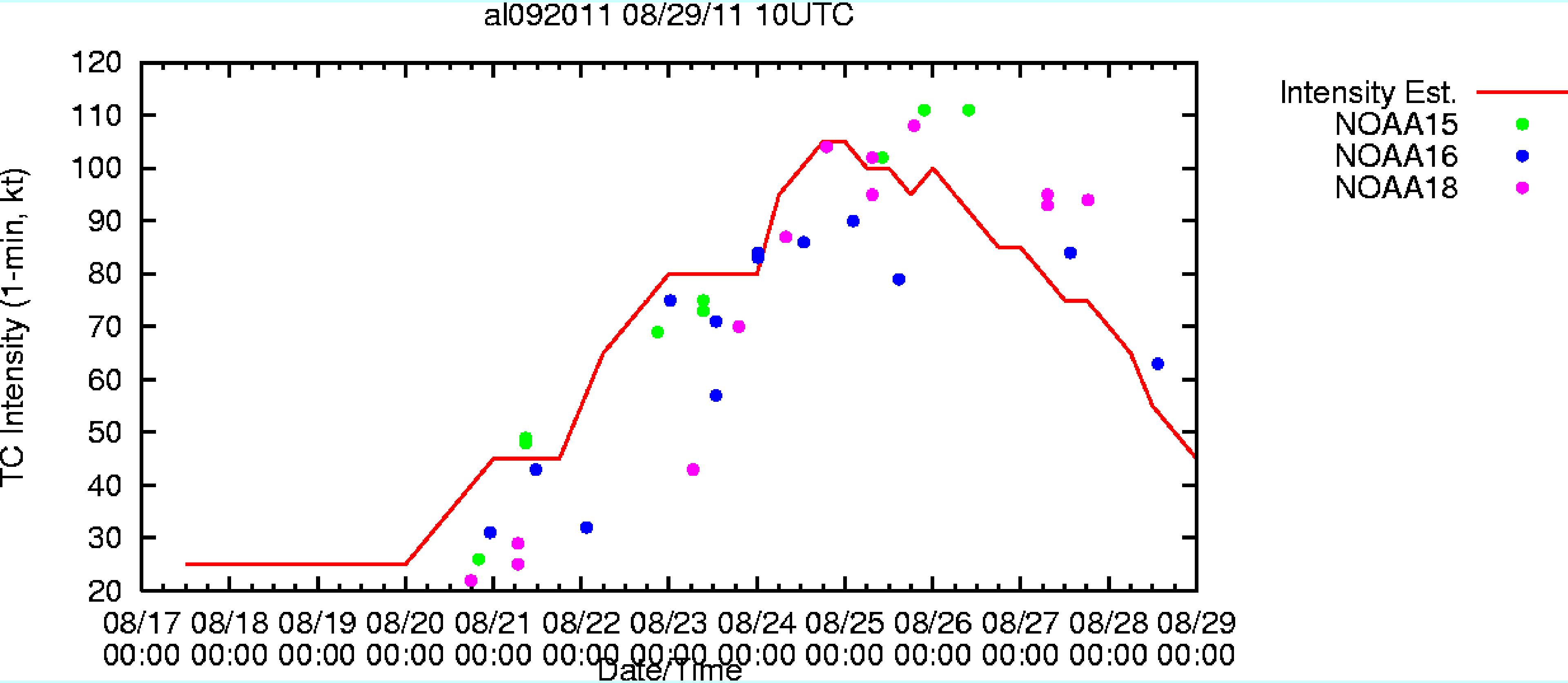
- CIRA AMSU intensity and wind structure estimation
  - Hydrostatic integration of AMSU soundings to give P_{min} and V_{max}
  - Statistical bias correction
  - Also provides radii of 34, 50 and 64 kt winds
  - Transitioned to NCEP operations
- CIMSS AMSU intensity estimation
  - Uses channels sensitive to upper level warm core
  - Forward model to account for AMSU resolution, scanning geometry
  - Run in real time at CIMSS, provided to NHC in real time
- AMSU nonlinear balance winds
  - Run at NCEP as part of CIRA AMSU algorithm
  - Used as input to new operational multiplatform tropical cyclone surface wind analysis

AMSU Temperature Retrievals Hurricane Irene Example



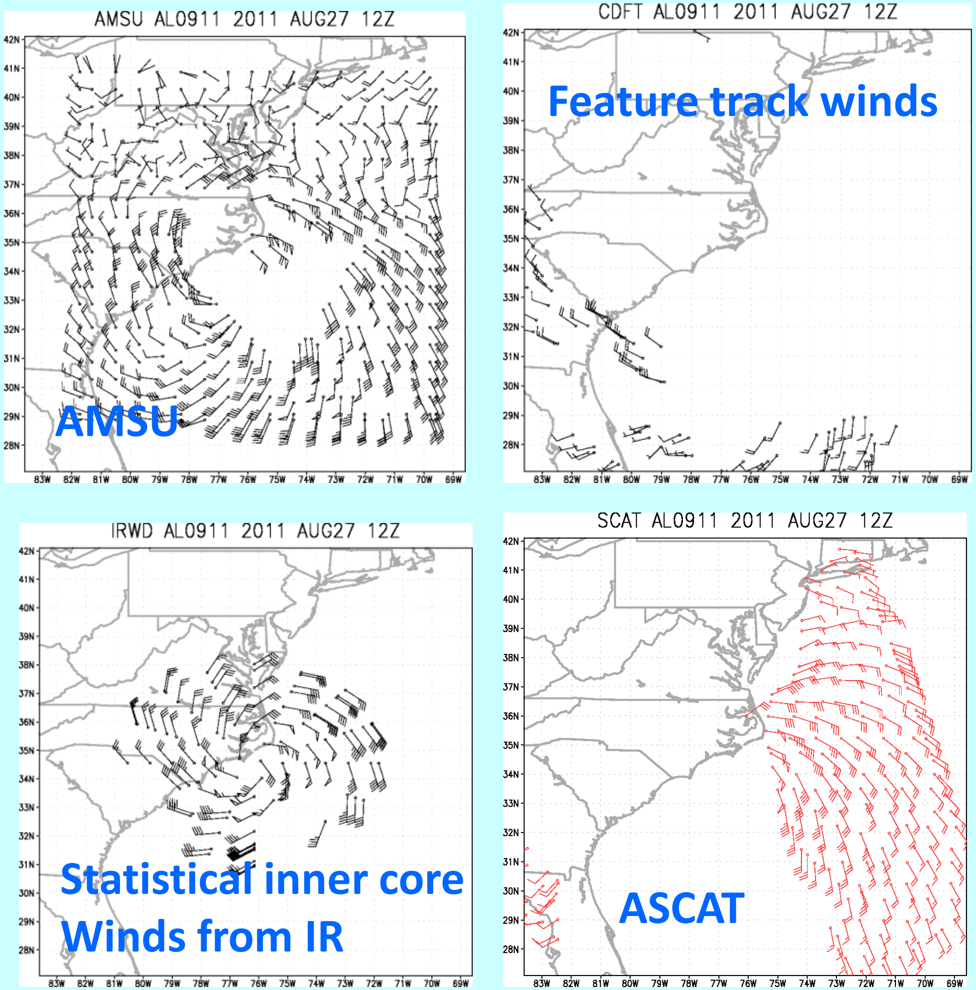


Sample AMSU Products from Hurricane Irene (2011)

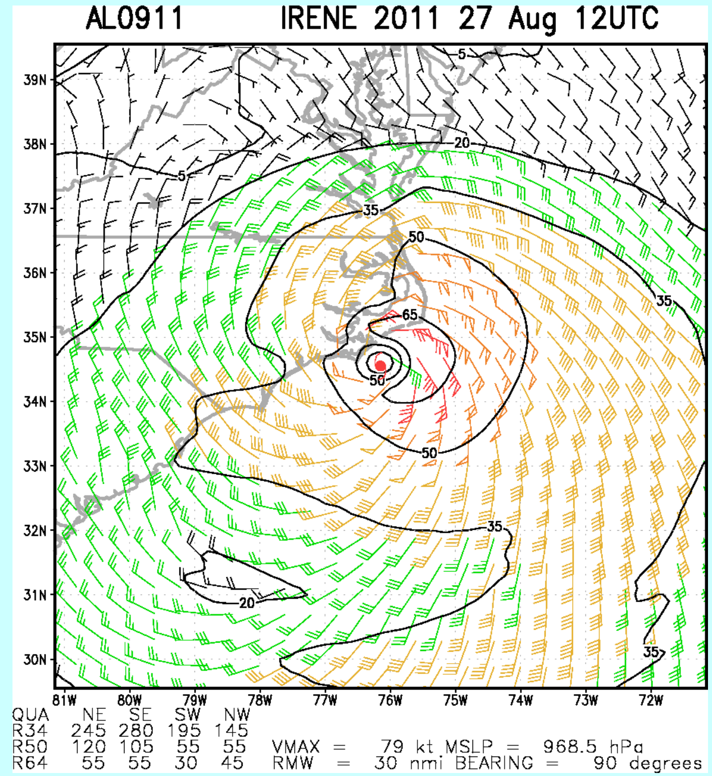


CIRA AMSU Intensity Estimates

Sample AMSU Products from Hurricane Irene (2011)

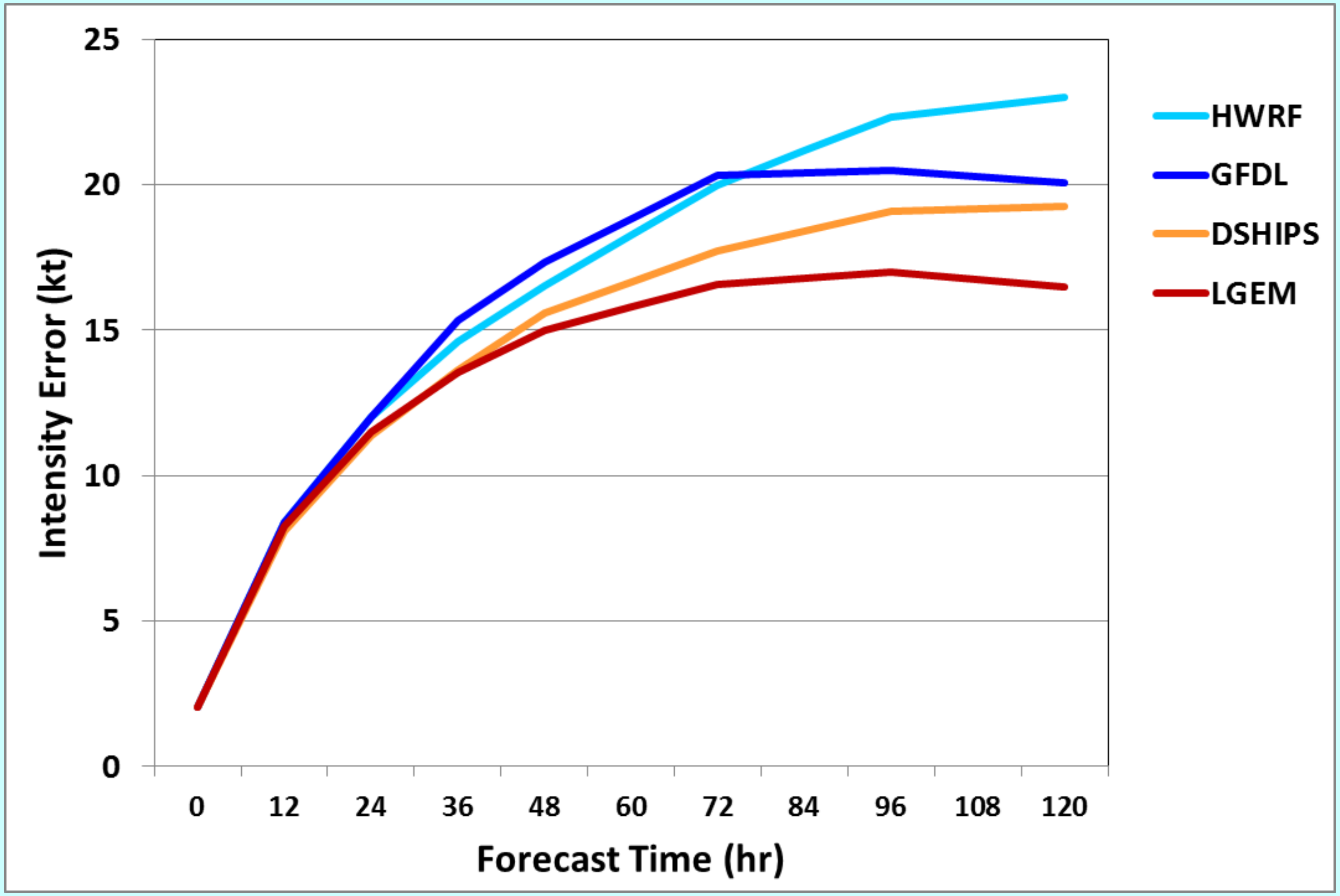


Satellite Input



Final Wind Analysis

Operational Atlantic Intensity Forecast Model Errors (2007-2011)



HWRF, GFDL are regional coupled ocean/atmosphere models
DSHIPS, LGEM are statistical models

Logistic Growth Equation Model (LGEM)

$$dV/dt = \kappa V - \beta(V/V_{mpi})^n V$$
$$\quad(A) \qquad\qquad (B)$$

Term A: Growth term, related to shear, structure, etc

Term B: Upper limit on growth as storm approaches its maximum potential intensity (V_{mpi})

LGEM Parameters:

$\kappa(t)$	Growth rate (from shear, instability, etc)
β	MPI relaxation rate (constant)
$V_{mpi}(t)$	MPI (from SST and sounding)
n	"Steepness" parameter (constant)

LGEM might be improved by estimating $V_{mpi}(0)$ and instability contribution to $\kappa(0)$ from ATMS/CrIS soundings.

Maximum Potential Intensity Theory (Emanuel 1988, Bister and Emanuel 1998)

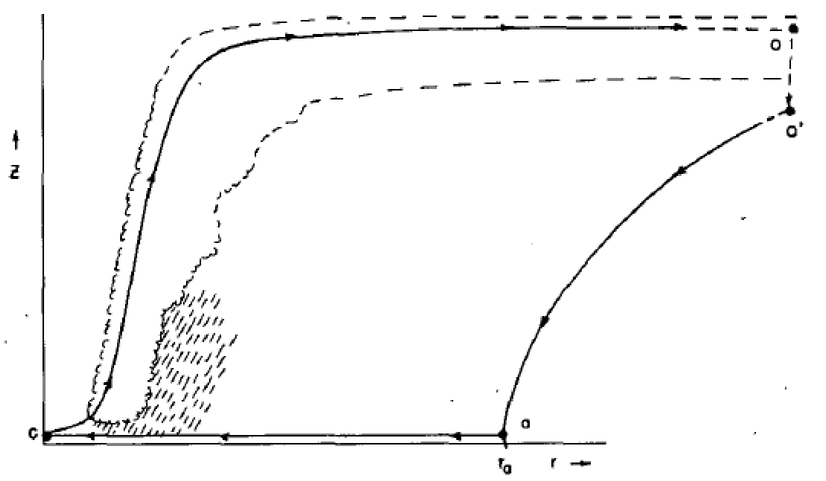


FIG. C1. Illustrating the path integral for the Carnot cycle. Points o and o' are taken to lie at very large radius.

$$V^2 = \frac{T_s - T_o}{T_o} \frac{C_k}{C_D} (k^* - k).$$

T_s, T_o, k^*, k can be estimated from the SST and a sounding.

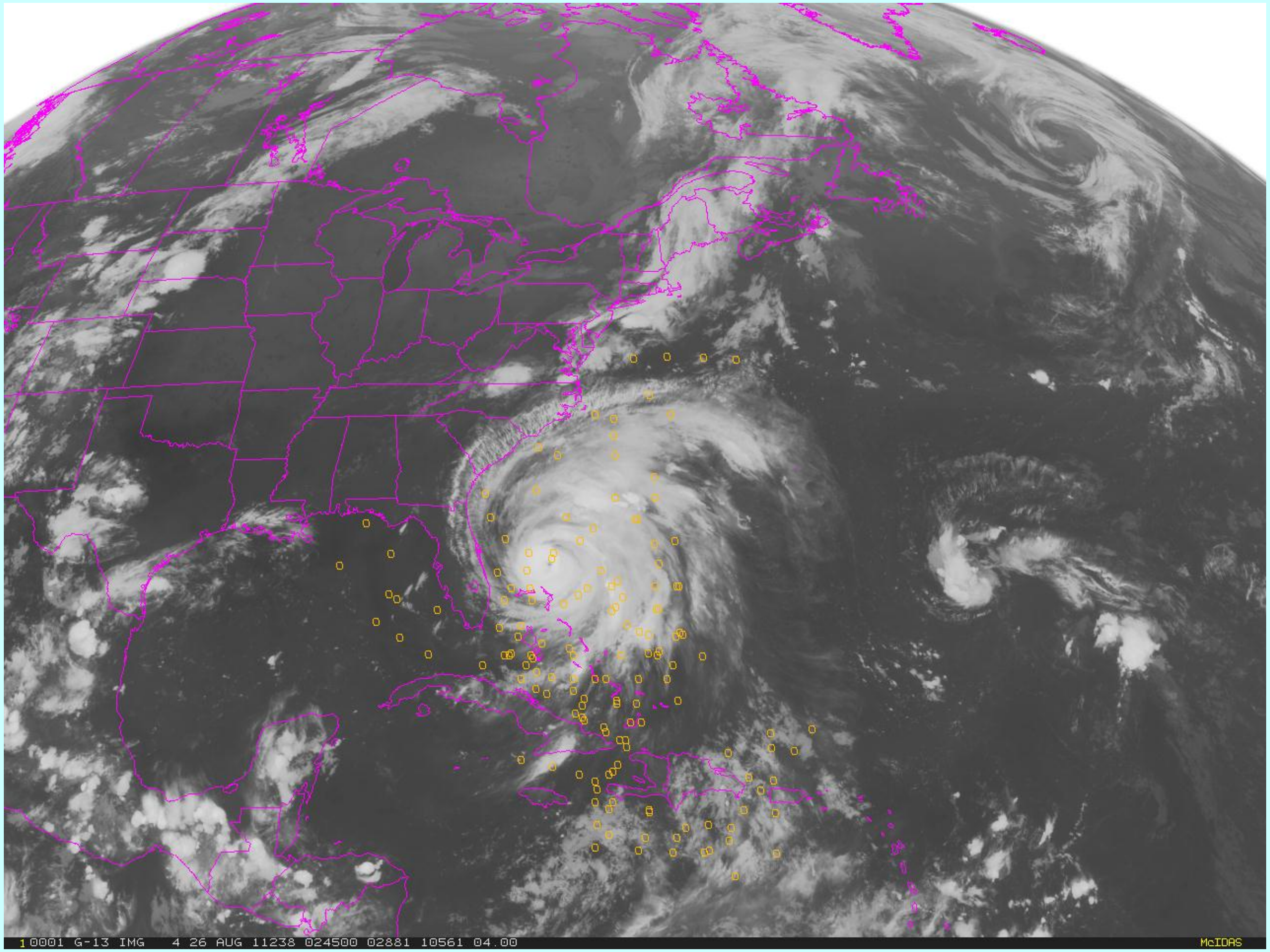
C_k/C_D= specified ratio of surface exchange coefficients

Tropical Vertical Instability

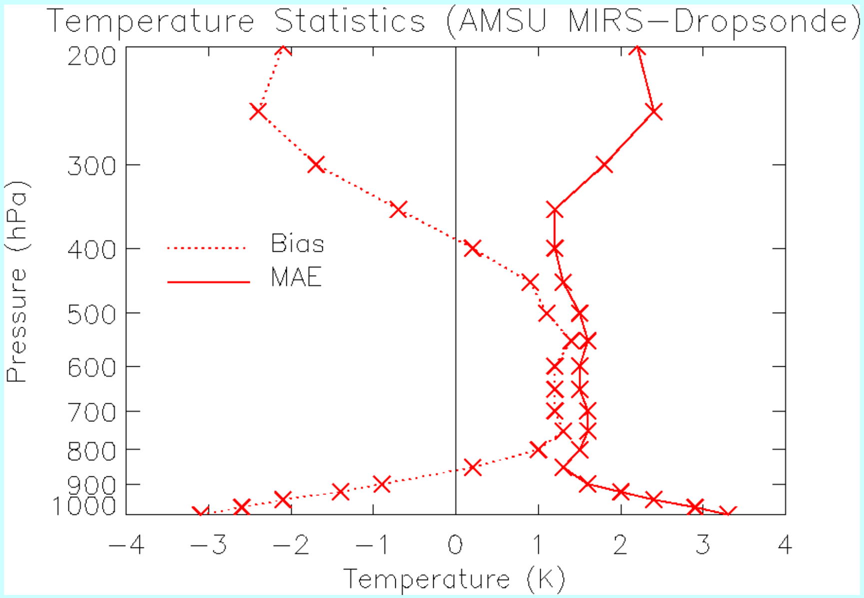
- Traditional CAPE variable dramatically over estimates vertical velocity
  - CAPE from Jordan sounding gives ~80 m/s
- Add entrainment, weight of condensate and ice phase to parcel calculation
- Tropical vertical instability (TVI) parameter is average vertical velocity of generalized parcel model
- LGEM growth rate proportional to TVI
- TVI can be estimated from ATMS/CrIS sounding in storm environment

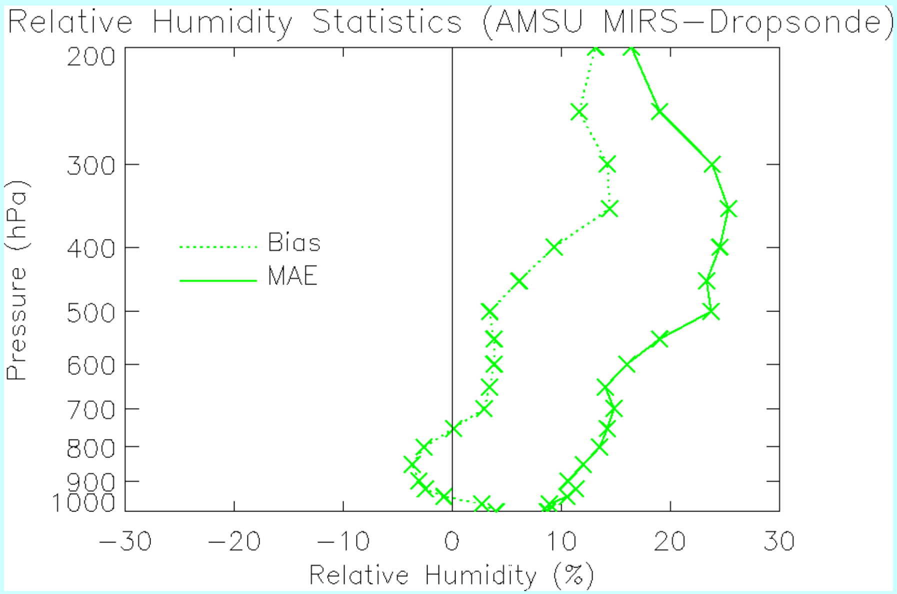
NOAA Gulfstream Jet Dropsondes for Hurricane Irene Aug 22-27, 2011

(Ground truth for MPI and TVI from AMSU)

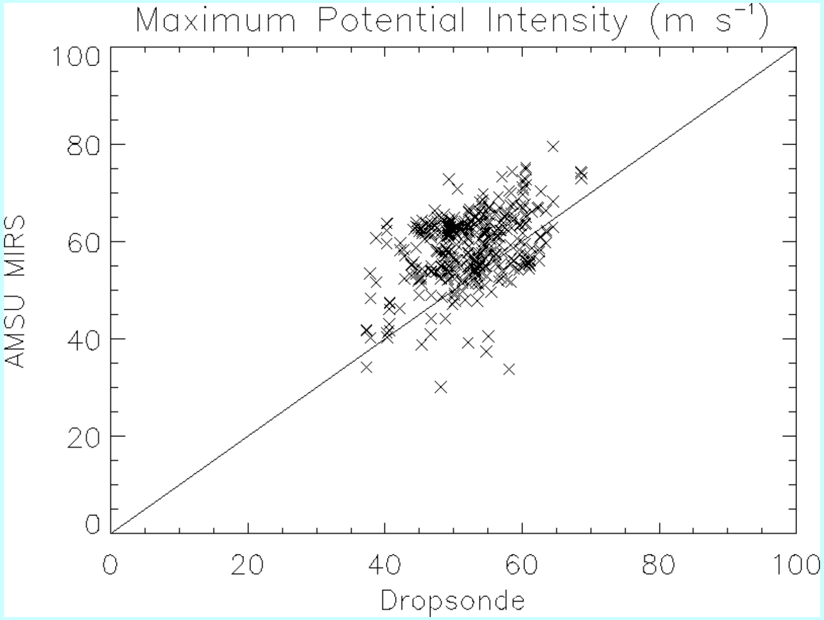


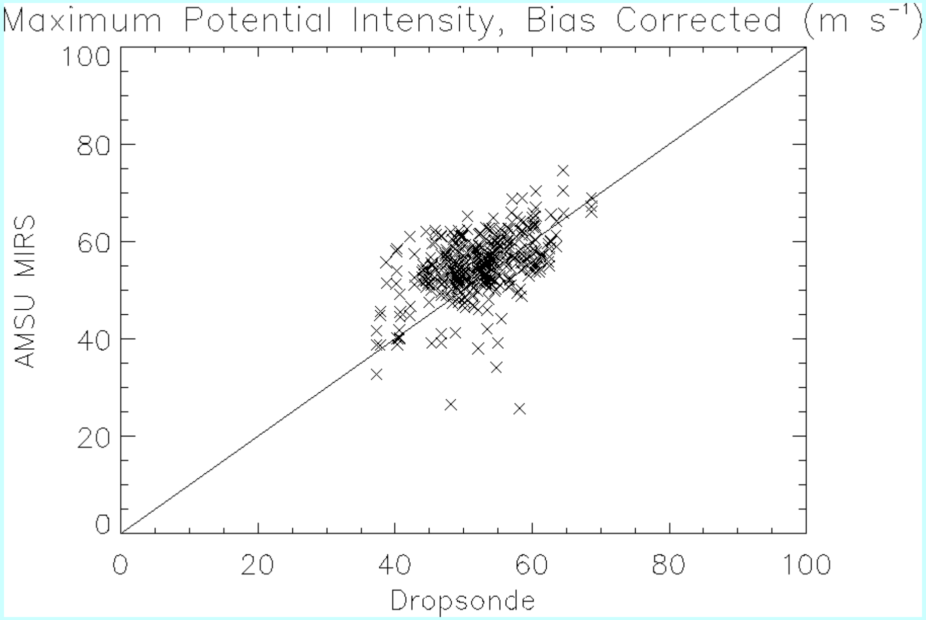
T, RH Error Statistics for MIRS AMSU Retrievals in Hurricane Irene Environment



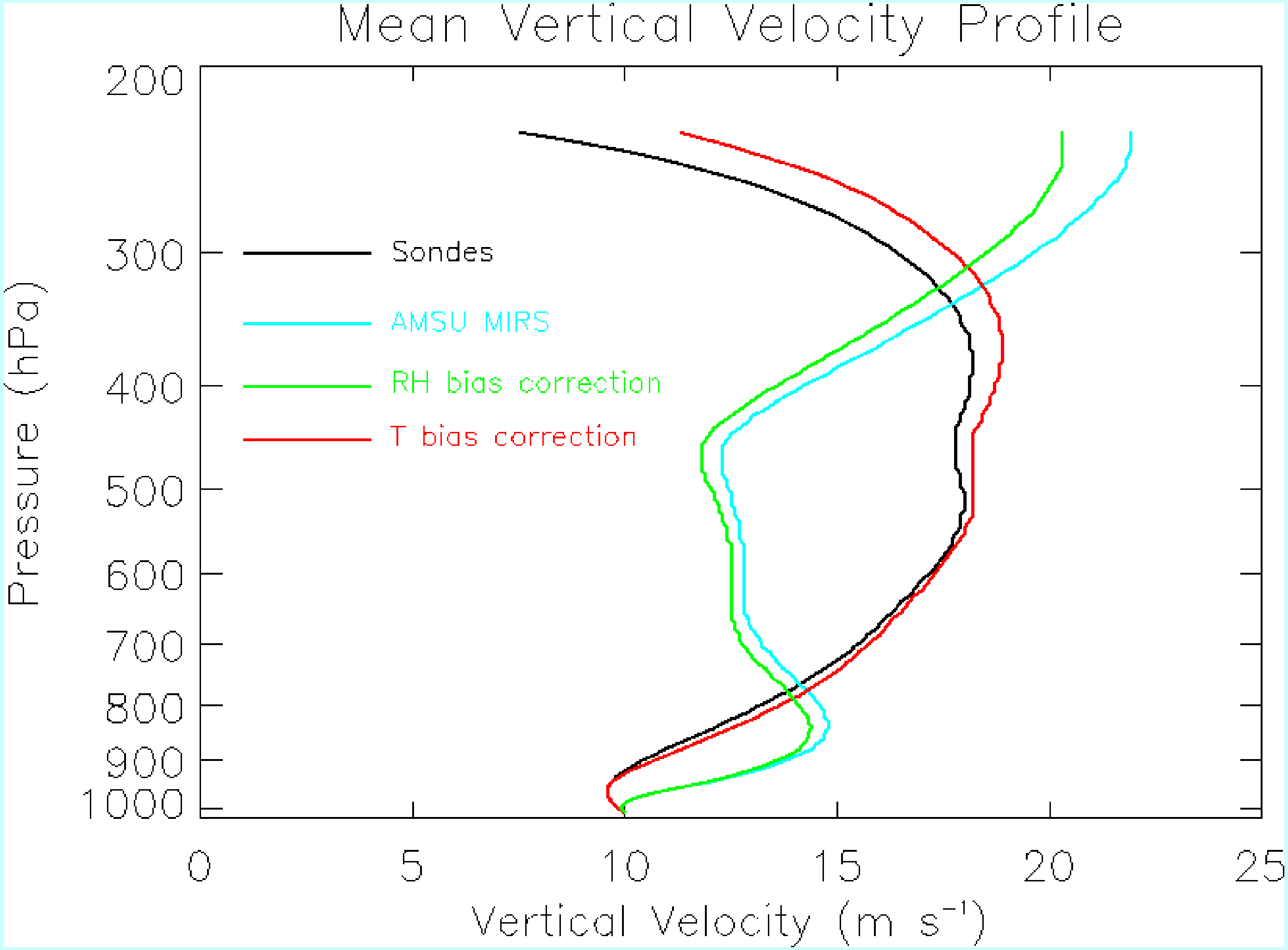


Maximum Potential Intensity Estimation in Irene's Environment

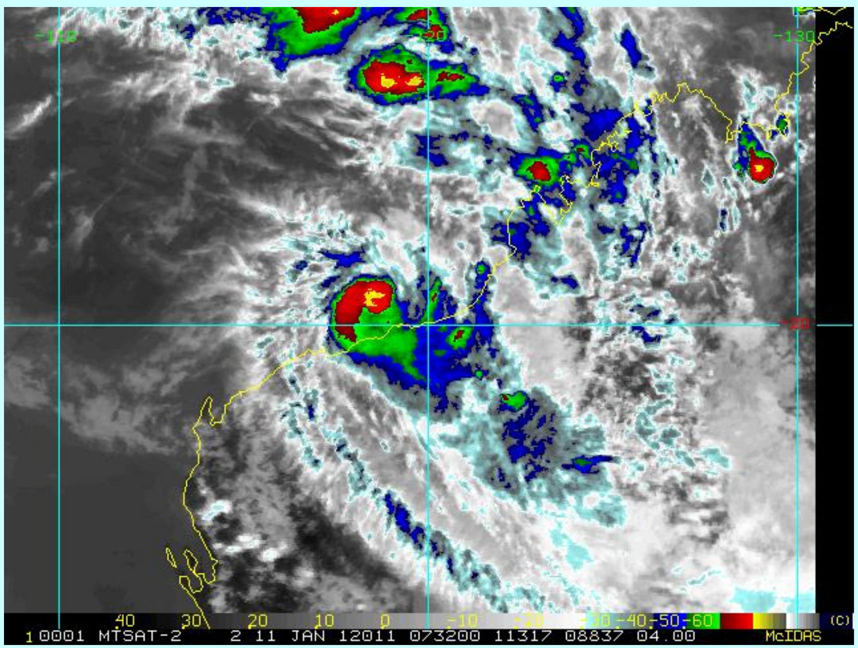




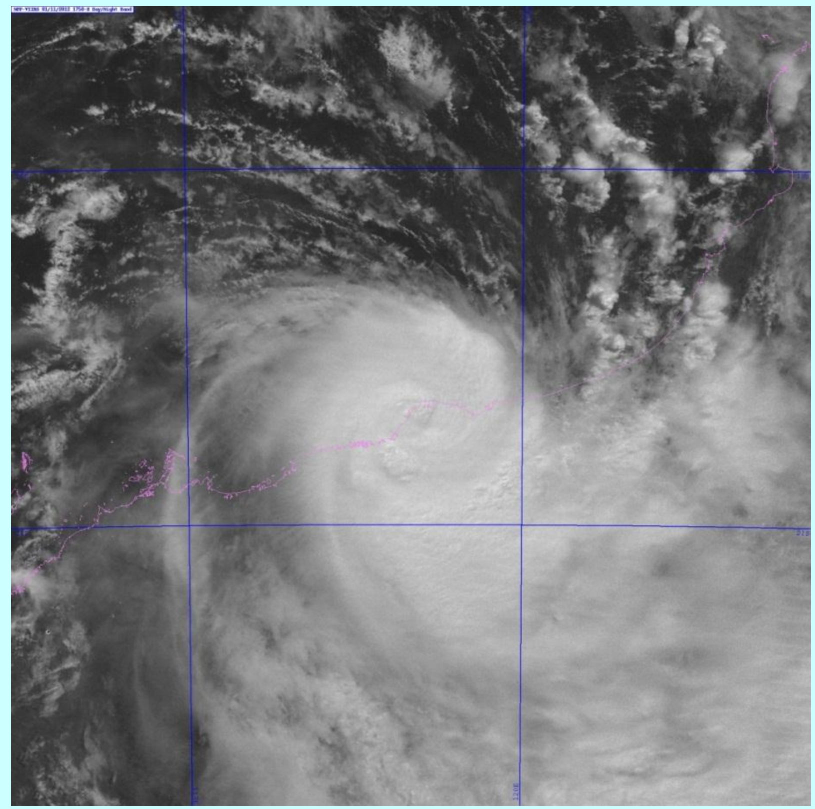
Tropical Vertical Instability in Irene's Environment



Day-Night Band VIIRS Image
Cyclone Heidi Landfall NW Australia
11 Jan 2012 1750 UTC (1:50 AM local)



MT-Sat IR Window Channel



VIIRS Day-Night Band

Summary

- AMSU T/RH soundings can be used to estimate tropical cyclone max wind and wind field using hydrostatic and nonlinear balance
- ATMS/CrIS soundings should better resolve warm core due to increased horizontal resolution
- ATMS/CrIS soundings have potential to improve intensity forecasts
  - Improved estimates of MPI and tropical vertical instability
  - AMSU retrievals require bias correction
- VIIRS in combination with GOES can improve center estimation

- *CIRA seeking Post Doc to work on TC applications of NPP and JPSS*